

Oxygen rich cool stars in the Cepheus region, New observations. III.

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Abstract

We present moderate resolution CCD spectra and R photometry for seven KP2001 stars. We revised the spectral classification of the stars in the range λ 3900 - 8500 Å. On the bases of light curves of the NSVS (Northern Sky Variability Survey) database we classify KP2001-18 as a semi regular and KP2001-176 as Mira type variables. For all observed objects NSVS phase - dependence light curve analysis and variability type classification was performed with the VStar Software. Using period - luminosity relation we computed MK magnitudes and the distances to variables.

Key words: stars: spectral classification: variables: distances

1 Introduction.

In this paper, third in this series, we continue spectroscopic and photometric study of oxygen-rich stars from KP2001 catalogue [1] in Cepheus direction. First two papers [2, 3] of the present series are devoted to clarify the nature of 20 late type stars. In this paper we present moderate resolution CCD spectra for seven stars from KP2001 catalogue. The luminosity classes and the distances are derived for them.

2 Spectroscopic and photometric observations.

Moderate resolution CCD spectra for seven KP2001 stars are obtained in the range λ 3900 - 8500 Å, dispersion 3.9/pixels, with the 1.52 m Cassini telescope of the Bologna Astronomical Observatory (Italy) at Loiano, equipped with the Bologna Faint Objects Spectrometer and Camera (BFOSC) and 1300x1300 pixel EEV P1129915 CCD. Photometric observations in R-band were also obtained with BFOSC in the same dates as the spectra. Table 1 presents the Journal of our observations, as well as the derived magnitudes and spectral types. The columns have the following meaning: column 1 KP2001 number in the list [1], column 2 date of observation, column 3 R band magnitudes, column 4 spectral types presented in KP2001 catalogue, column 5 - new spectral subtypes, revised from our CCD data, derived as described below. All the spectroscopic and photometric observations were processed by means of standard IRAF procedures.

We determined spectral subtypes of stars via side-by side comparison with spectra of standard stars (from M0 to M9, giants and dwarfs) obtained with the same instrumentation. Fig.1, 2 and 3 presents our CCD spectra for the seven KP2001 stars.

3 Colors, variability and distances.

We used the determined spectral classification to measure a number of physical properties of our stars.

Table 1: JOURNAL OF OBSERVATIONS, PHOTOMETRIC RESULTS AND SPECTRAL CLASSIFICATION

KP2001 Number	date of observation	R mag	Previous Sp. Subtype[1]	CCD Sp. Subtype
8	12.12.2014	13.5 ± 0.1	M3	M3III
16	27.01.2015	13.2 ± 0.1	M2	M2III
18	27.01.2015	10.8 ± 0.1	M5	M7III
176	12.12.2014	14.6 ± 0.1	M6	M8III
194	12.12.2014	11.9 ± 0.1	M6	M6III
243	29.12.2013	-	M4	M2III
251	07.09.2011	-	M7	M10III

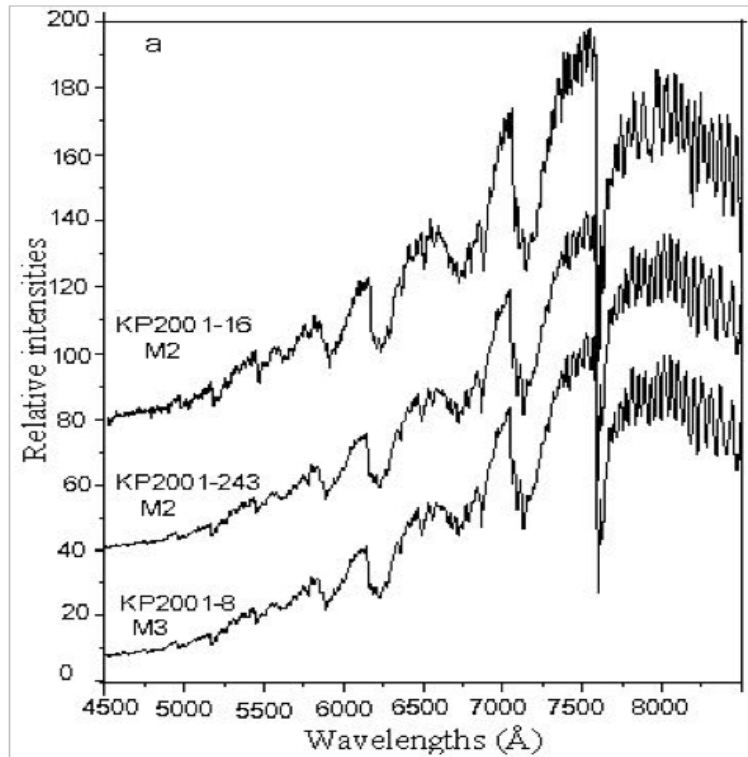


Figure 1: Spectra of some KP2001 stars. Flux in arbitrary units, wavelengths in Angstrom.

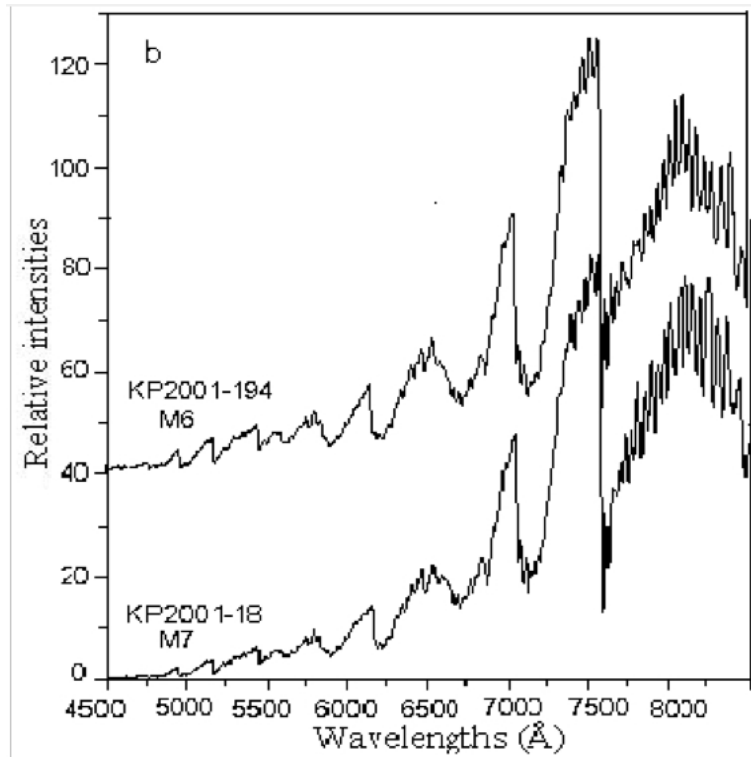


Figure 2: Spectra of some KP2001 stars. Flux in arbitrary units, wavelengths in Angstrom.

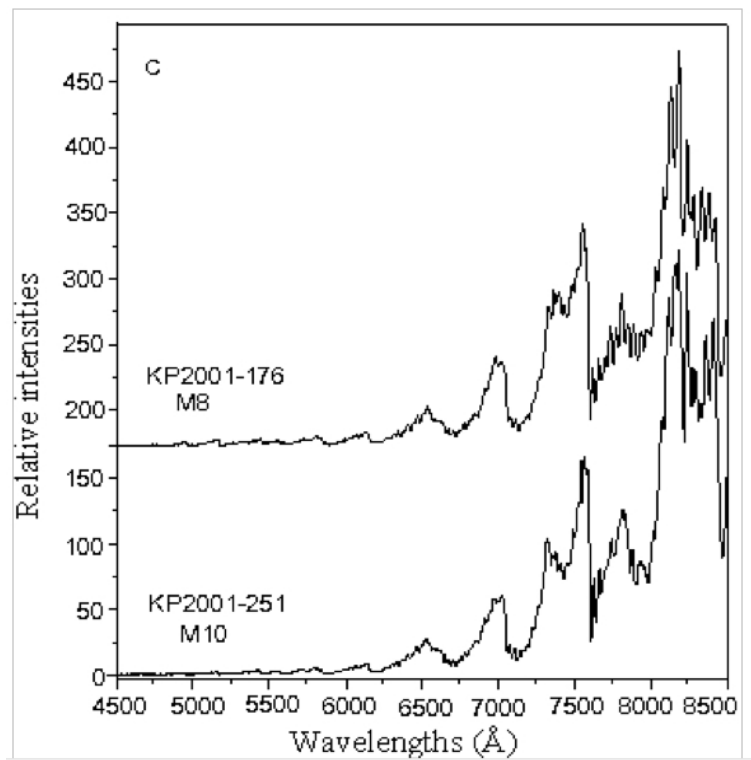


Figure 3: Spectra of some KP2001 stars. Flux in arbitrary units, wavelengths in Angstrom.

Table 2: MAGNITUDES OF THE OBSERVED STARS

KP2001	J	H	K
Number	mag.	mag.	mag.
8	9.056 ± 0.018	7.829 ± 0.031	7.444 ± 0.018
16	-	7.398 ± 0.031	6.934 ± 0.027
18	8.550 ± 0.020	3.923 ± 0.184	3.226 ± 0.242
176	5.245 ± 0.238	6.770 ± 0.031	6.116 ± 0.022
194	7.849 ± 0.035	5.643 ± 0.038	5.193 ± 0.024
243	6.791 ± 0.021	5.933 ± 0.051	5.510 ± 0.021
251	7.175 ± 0.025	3.125 ± 0.218	2.514 ± 0.304
	4.296 ± 0.256	-	-

Table 3: INFRARED COLORS AND COLOR EXCESS OF SEVEN KP2001 TARGETS TRANSFORMED TO THE BESSEL & BRETT SYSTEM

KP2001	J-H	E(J-H)	H-Ks	E(H-Ks)	E(B-V)	AV	AK
number	mag.	mag.	mag.	mag.	mag.	mag.	mag.
8	1.29 ± 0.04	0.39	0.36 ± 0.04	0.12	0.85	2.65	0.29
16	1.22 ± 0.04	0.35	0.44 ± 0.04	0.22	1.06	3.31	0.36
18	1.39 ± 0.30	0.43	0.67 ± 0.30	0.36	1.52	4.74	0.52
176	1.15 ± 0.05	0.17	0.63 ± 0.04	0.20	0.5-1.0	1.56+	0.15+
194	1.22 ± 0.04	0.26	0.42 ± 0.05	0.12	0.67	3.12	0.36
243	1.31 ± 0.06	0.44	0.39 ± 0.06	0.17	0.81	2.09	0.23
251	1.24 ± 0.34	0.22	0.58 ± 0.37	0.10	0.56	2.53	0.27
						1.75	0.19

3.1 Colors.

The observed targets are located at low galactic latitudes, therefore the observed colors are strongly affected by interstellar reddening which is the first important quantity to be determined. For this purpose we used the infrared colors, applying the same diagrams as in the papers [4-8]. A detailed discussion of the intrinsic colors of late type M giants and dwarfs can be found in the paper by Bessell & Brett [4]. 2MASS infrared (JHKS) magnitudes are available at <http://irsa.ipac.caltech.edu/2mass>. In table 2 we present the original JHKS magnitudes from 2MASS catalogue for our stars.

In Fig. 4 we reproduced the Fig. A3 of paper [4], where we added our stars after having transformed the original 2MASS magnitudes to the Bessell & Brett system using the formulae given in Explanatory Supplement to the 2MASS Second Incremental Data Release at

<http://www.ipac.caltech.edu/2mass/release/second/doc/sec6-3.html> and in Appendix A by Carpenter [9]. Fig. A3 of paper [4] is the (J-H) versus (H-K) diagram showing schematically the regions occupied by G5 to M6 dwarf and giants, SR and LPV carbon stars, and SR and LPV M7-M10 AGB stars. The arrow indicates the direction of interstellar reddening.

We present in Table 3 the observed J-H and H-K_s colors. From the spectral subtype determinations we deduced the expected intrinsic (reddened) values presented in Table III of paper [4] in order to move the experimental values to intrinsic positions and compute the extinction of the stars. For the

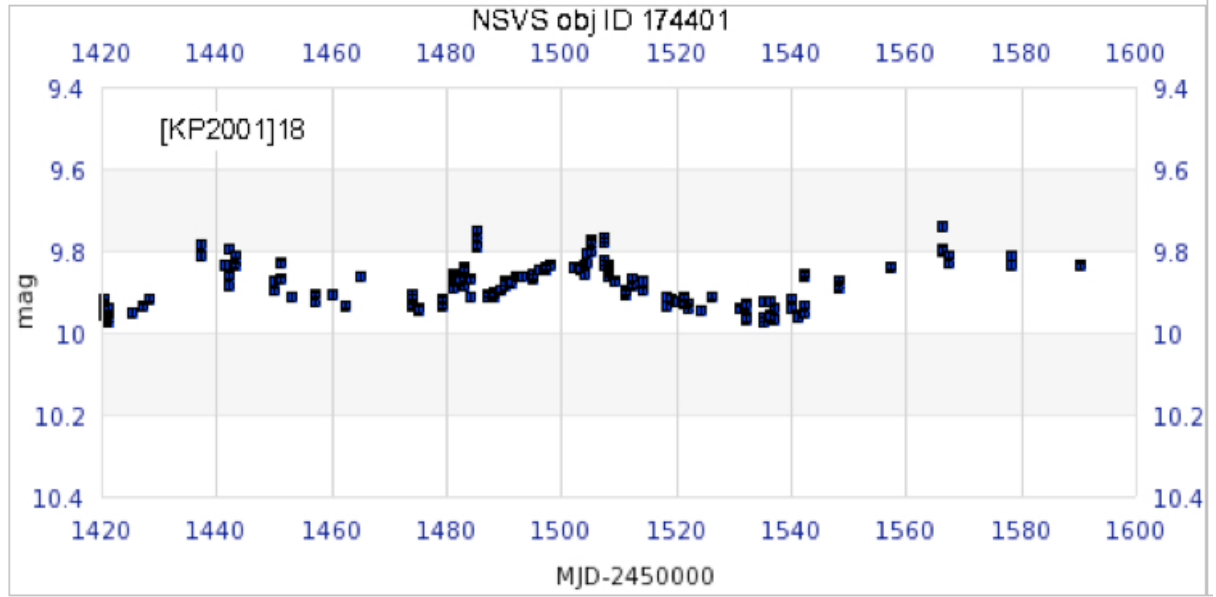


Figure 5: NSVS phase dependence light curves for KP2001-18.

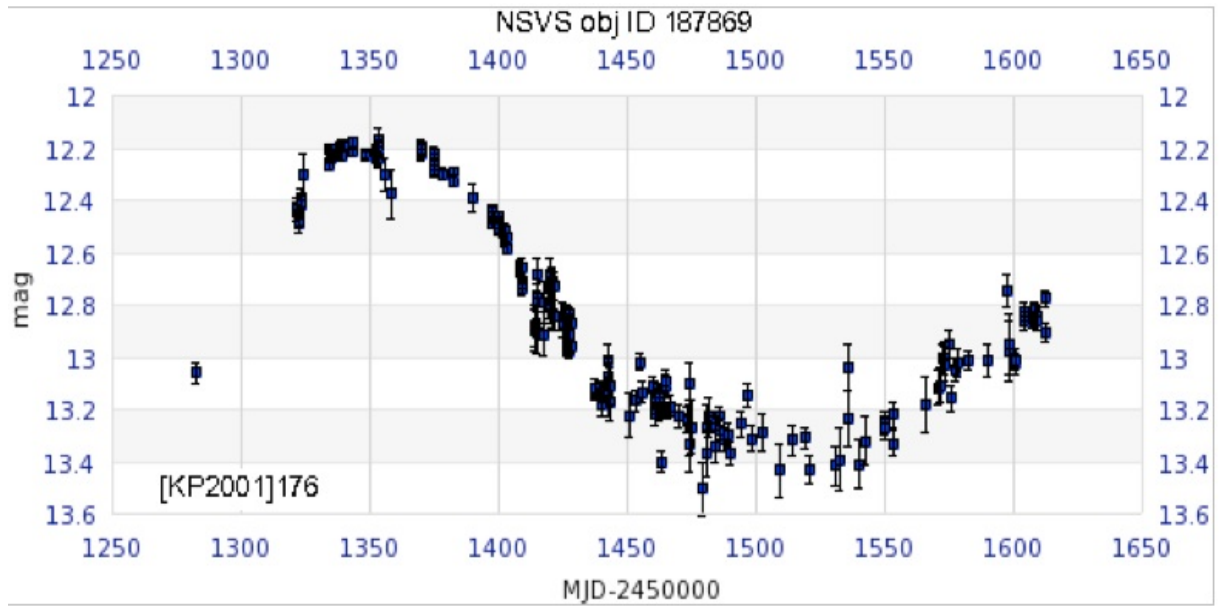


Figure 6: NSVS phase dependence light curves for KP2001-176 star.

3.3 Absolute magnitudes and Distances.

To estimate the absolute magnitudes and distances to the variable stars we applied the same procedures of paper [1], using updated Period Luminosity (PL) relations. We first computed the absolute K magnitude for O rich Mira variables applying the formula by [17]:

$$M(K) = -3.51 \pm 0.20 \cdot (\text{Log}(P) - 2.38) - 7.25 \pm 0.06 \quad (3)$$

while for the SR variable KP2001-18 we applied the new PL relation given by [14]:

$$M(K) = -1.34 \pm 0.06 \cdot \text{Log}(P) - 4.5 \pm 0.35 \quad (4)$$

Then we have computed the distances, also taking into account the two possible values of the extinction in K magnitude for KP2001-176. For Mira type variables the distances are estimated also using equation (3) presented in first Paper[2];

$$M(\text{bol}) = 2.80 - 3.0 \cdot \text{Log}(P) \quad (5)$$

The apparent bolometric magnitude $M(\text{bol})$ for KP2001-176, and 251 are determined by applying the bolometric correction $BC(K)$ to the $m(K)$ reddening corrected magnitude (see [18] for details):

$$mbol. = m(K) + BC(K) \quad (6)$$

In equation (6) we adopted the value $BC(K) = 2.8$ obtained using the calibration $BC(K)$ vs. ($K-[12]$) index for O rich Miras given in Fig. A3 of the same paper [18]. Note that IRAS 12 μm magnitude was calculated from the densities quoted in the catalogue following the prescription given in [19].

The results for KP2001-18, 176 and 251 are presented in Table 4.

Table 4: Period, absolute magnitude and distance of KP2001-18, 176, 251

KP2001 Number	Var.type	Period Days	m_{bol} mag.	M_{bol} mag.	M_K mag	D(pc) from M_{bol}	D(pc) from M_K
18	SR	60	-	-	-6.88 ± 0.35	-	810 ± 100
176	Mira	330	8.71	-4.71	-7.70 ± 0.12	4850	5100 ± 100
251	Mira	347	5.12	-4.82	-7.82 ± 0.09	980	1100 ± 150

For the stars, KP2001-16 and 243 the approximate distances can be estimated, using Guide Star Catalogue (GSC2.3) [15] (Vizie Online Catalogue I/305) V magnitudes, and adopting absolute visual magnitudes for M2III=-1.1 (see for more details at <http://www.handprint.com/ASTRO/spec-class.html#luminositycodes>)

Table 5 presents data for KP2001-16 and 243 stars

4 Concluding remarks.

In this paper, third in this series, we continue spectroscopic and photometric study oxygen-rich stars from KP2001 catalogue in Cepheus direction. To study our stars we followed the same methodological

Table 5: Absolute magnitude and distance of KP2001-16 and 243

KP2001 Number	mv(GSC2.3) mag.	M_V mag.	Distance pc
16	14.21	-1.1	2510
243	12.93	-1.1	2000

approach as in [1]. For seven new targets we obtained moderate resolution CCD spectra which allowed to determined spectral types and luminosity classes. From the near infrared colors we measured the interstellar extinction; for the variable stars we could apply the Period-luminosity relations from which we then derived absolute magnitudes and distances. All the variable stars studied in paper [1] and in the present paper have periods automatically determined by the NSVS survey, based on a relatively short monitoring. We already started a long-term monitoring not only to these stars, but to all the KP2001 stars in the Cepheus region in order to improve the value of the periods for the known variable and to look for variability in those not yet studied. Actually we intend to apply the same analysis to all the 257 stars with the purpose of clarifying their nature and compare the ratio of Carbon to Oxygen-rich giant stars in this region of the Milky Way. In addition we are working on the infrared color color diagrams involving IRAS, AKARI, WISE data, facing with the difficulties due to the interstellar extinction toward the Cepheus direction.

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